OPTIMIZATION OF A MINIATURIZED ETHERNET 10 GBITS/S 8 CONDUCTORS INTERCONNECT FOR HARSH ENVIRONMENTS

Y. Boujmad\textsuperscript{1}, C. Bermond\textsuperscript{1}, P. Artillan\textsuperscript{1}, O. Gavard\textsuperscript{2}, M. Prudhom\textsuperscript{2}, F. Khalili\textsuperscript{2}, E. Husson-Charlet\textsuperscript{2}, J.-P. Barbosa\textsuperscript{2}, B. Flechet\textsuperscript{1}

\textsuperscript{1} IMEP-LAHC, Université Savoie Mont Blanc, Chambéry, France.
\textsuperscript{2} Amphenol-Socapex, Thyez, France.
Overview

- Design of a high speed Ethernet contact for military and aerospace industries

- Category 6A Ethernet standard
- Bitrate: 10 Gbits/s

- MIL-DTL-38999 and EN3645
- Thermal constraints: [-65°C, 200°C]
- Vibratory constraints: 10 to 20 G per axis

- Miniaturization
- Contacts into a confined space
Ethernet contact prototype #1

- 8 pins (4 differential pairs)
- Metal shield cross
- Cylindrical outer shell
- Thermoplastic polymer
- Female contact
- Male contact
- $D \approx 5\text{mm}$
- $L \approx 25\text{mm}$
**Category 6A Ethernet standard**

<table>
<thead>
<tr>
<th>Cat 6A criterions</th>
<th>Design optimization</th>
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<tr>
<td>Insertion Loss (IL)</td>
<td>Low dielectric losses</td>
</tr>
<tr>
<td>Return Loss (RL)</td>
<td>$Z_c \approx 100\Omega$</td>
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<td>NEXT loss (NL)</td>
<td>Internal shielding</td>
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Goal: 10 Gbits/s

$F = [1\text{MHz}-500\text{MHz}]$
Outline

I. 2D-3D electromagnetic simulation approaches

II. Prototype #1: validation of measurements & simulation tools

III. Prototype #2: optimized Ethernet contact

IV. Perspectives
2D-3D electromagnetic simulation approaches

3D simulation tool

- **Return Loss (RL)**
  - Differential port 5

- **Insertion Loss (IL)**

- **NEXT Loss (NL)**
  - Differential port 1
  - Differential port 2

- Simulation using ANSYS HFSS 3D full wave solver
- BW = [10MHz, 1GHz]
The contact Ethernet #8 1.0 is represented as 7 cascaded segments.

- Segments are modeled under ANSYS 2D Extractor solver.

- RLGC matrix of every segment [8x8]
[RLGC] matrix of every segment [8x8]

\[
[ABCD]_i = \begin{bmatrix}
Y^{-1}_E i \cdot \coshm(\Gamma_i) \cdot Y_{E_i} & Z_{c_i} \sinhm(\Gamma_i) \\
\sinhm(\Gamma_i) \cdot Z^{-1}_c & \coshm(\Gamma_i)
\end{bmatrix}
\]

\[\Gamma_i = \sqrt{Y_{E_i} \cdot Z_{M_i}} \cdot l_i\]
\[Z_{c_i} = \sqrt{Y_{E_i}^{-1} \cdot Z_{M_i}}\]
\[l_i: \text{segment length}, i \in [1,7]\]

[ABCD]_i matrix of every segment [16x16]

\[\begin{bmatrix}
[ABCD]_1 \\
\vdots \\
[ABCD]_7
\end{bmatrix} = \prod_{i=1}^{7} [ABCD]_i\]

[ABCD] matrix of the contact [16x16]

\[Y_{E_i} = G_i + j\omega C_i\]
\[Z_{M_i} = R_i + j\omega L_i\]
2D-3D electromagnetic simulation approaches

\[ [S]_{se} = \left( [(A) + (B) \cdot Z_0^{-1} - (C) \cdot Z_0 - (D)] \right) \cdot \text{den}^{-1} \]

\[ 2 \cdot \left( [(A) \cdot (D) - (B) \cdot (C)] \right) \cdot \text{den}^{-1} \]

\[ \{- [A] + [B] \cdot Z_0^{-1} - (C) \cdot Z_0 + [D] \} \cdot \text{den}^{-1} \]

\[ \text{den} = [A] + [B] \cdot Z_0^{-1} + [C] \cdot Z_0 + [D] \]

\[ [S]_{mm} = P_{mm} \cdot [S]_{se} \cdot P_{mm}^{-1} \]

\[ [S]_{mm16 \times 16} = \begin{bmatrix} [S]_{dd8 \times 8} & [S]_{dc8 \times 8} \\ [S]_{cd8 \times 8} & [S]_{cc8 \times 8} \end{bmatrix} \]

\[ [S] \text{ differential mode matrix of the contact [8x8]} \]

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Prototype #1: validation of measurements & simulation tools

NEXT loss & Return loss measurement configuration

Insertion loss measurement configuration

8 SMA

Ethernet cable

Ethernet #8 contact

DUT
soudé = welded
Younes Boujmad; 03/06/2019
Prototype #1: validation of measurements & simulation tools

NEXT loss:

![Graph showing NEXT loss comparison]

- Measured NEXT > Simulated NEXT
- Improve the test fixture

The NEXT is in accordance with the category 6A standard

Complex assembling of the metal cross

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Prototype #1: validation of measurements & simulation tools

Insertion loss:

IL results: 2D segmentation approach ≡ 3D full wave simulation ≡ VNA measurement

The IL is not in accordance with the category 6A standard
Prototype #1: validation of measurements & simulation tools

Return loss:

RL results: 2D segmentation approach ≡ 3D full wave simulation ≡ VNA measurement

😊 RL level is 8.5 dB higher than the value imposed by the Ethernet cat 6A standard
 Prototype #1: validation of measurements & simulation tools

- TDR measurement: 60Ω < Zc < 70Ω for the contact #1
The 2D modeling tool can be used for the optimization procedure.

The first prototype doesn’t meet the category 6A standard.
I. Combined 2D-3D electromagnetic simulation approaches

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Prototype #2: optimized Ethernet contact

- Optimization of the impedance matching by:
  - Including air gaps in the dielectric
  - Modifying the shielding
  - Decreasing the diameter of the pins

- TDR measurement:
  $90\Omega < Z_c < 100\Omega$ for the optimized contact (prototype #2)
Prototype #2: optimized Ethernet contact

Characteristic Impedance Optimization => Improves the IL and RL compared to the category 6A standard
Integrating the shield in a single piece of dielectric

The NEXT in accordance with cat 6A
The optimized prototype #2 meets the category 6A standard

The optimized contact #2 is designed with a single piece of dielectric which facilitates contact assembly
Perspectives

- Broadband characterization of the dielectric polymer using coaxial lines [10 MHz - 12 GHz]
- Harsh environment qualification (temperatures and vibrations)
- Meet the industry standard for fabrication
- Conception of a mold for the dielectric part
- Final optimization leading to Ethernet #3 contact
THANK YOU FOR YOUR ATTENTION

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